1967-06

Application of the general purpose simulator TRANSIM to shipyard tool issue problems

Phillips, George Lincoln, Jr.

Monterey, California. U.S. Naval Postgraduate School

http://hdl.handle.net/10945/11666

APPLICATION OF THE GENERAL PURPOSE SIMULATOR "TRANSIM" TO SHIPYARD TOOL ISSUE PROBLEMS

GEORGE LINCOLN PHILLIPS

APPLICATION OF THE GENERAL PURPOSE SIMULATOR

"TRANSIM" TO SHIPYARD TOOL ISSUE PROBLEMS

by

George Lincoln Phillips, Jr.
Lieutenant Commander, United States Navy
B.S., Webb Institute of Naval Architecture, 1951

[redacted]

Submitted in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
June 1967

ABSTRACT

The general-purpose simulator TRANSIM, developed by the University of California at Los Angeles, Department of Engineering, is used to study shipyard problems in the issue of tools to workers engaged in overhaul of a carrier at a Naval Shipyard. The present system, tool issue from off-ship toolrooms, is compared with proposed systems using portable auxiliary toolrooms installed aboard the ship. Two alternate locations for auxiliary toolrooms are tested in various combinations with the presently installed pierside toolrooms. A model of the present system is constructed, and extended to include the proposed alternate systems. The systems are compared using Monte Carlo techniques, at two levels of population and at three levels of auxiliary toolroom capacity. Additional refinements are recommended, and uses of the TRANSIM method in extensions of the problem are indicated.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

ACKNOWLEDGMENTS

The author is indebted to Mr. A. M. Feiler, of Project TRANSIM, Department of Engineering, UCLA, and Asst. Professor S. H. Parry, Operations Analysis Department, Naval Postgraduate School, for their consideration and guidance. Further assistance from Mr. E. O. Fisher and Mr. Carlos Valdesuso of Project TRANSIM, and from Mr. E. E. Collins, Mr. J. Alguard, and Mr. M. J. Gralia, of the Puget Sound Naval Shipyard, is gratefully acknowledged. This study is a part of the continuing work of Project TRANSIM, conducted under the sponsorship of the Office of Naval Research, Department of the Navy, under Contract Nonr 233(89).

CHAPTER I

INTRODUCTION

The TRANSIM method of systems analysis is being evaluated as management tool for naval shipyards under a contract with the Office of Naval Research. The investigation presented in this thesis was performed in conjunction with the University of California at Los Angeles, Department of Engineering, and the Puget Sound Naval Shipyard, Bremerton, Washington, to determine the feasibility of use of the method in typical shipyard problems.

I. TRANSIM

The TRANSIM (TRANsportation SIMulator) was developed by the University of California, Los Angeles, as a general-purpose simulator to be used in analysis of transportation problems. It is more fully described in reports issued by the University[1,2] and will be described here only as necessary to demonstrate the general method of approach to the analysis of the system.

TRANSIM was originally designed under sponsorship of the Office of Transportation Research, in the Office of the Under Secretary for Transportation, U. S. Department of Commerce. TRANSIM has been successfully used to examine a wide range of transportation problems, ranging from iron-ore train operations to the examination of an entire marine port complex, and is described as follows:

> TRANSIM is a general-purpose simulator with a standard computer program which does not have to be modified from problem to problem. Its basic features can best be described

by comparison with conventional computer simulation techniques. In the conventional approach, the problem of preparing for the simulation analysis falls into two main task areas. First, a model of the system to be simulated is formulated, usually as a set of input data, mathematical relationships and logic that represent the real system and the interactions between the system's components. And, second, from such a model, a programmer structures a computer program that will "run" the simulation.

TRANSIM, on the other hand, has a single, standardized computer program which can be applied without modification to a wide range of different problem situations. This eliminates the second phase of the conventional approach -- the task of writing specific computer programs for each problem. With its standard computer program, the TRANSIM simulator assumes the characteristics of a specific situation when it is combined with an input data set describing the particular problem parameters...

In TRANSIM, a system problem situation is described in the input data set in real system terms as comprising trains, trucks, ships, terminals, traffic, docks, personnel, and the like.

TRANSIM models are made up of two basic system components, traffic units and operating elements. Traffic units are the vehicles, freight, commodities, information, and documentation which "flow" through the system. Operating elements are the facilities, equipment, and manpower which "service" or "process" traffic units during their flow through the system.

Each operating element of a system is represented in the simulator by a general program routine which has provisions for holding traffic units in delay while awaiting service, performing the service for a traffic unit, breaking down and consolidating traffic units, and accumulating traffic units in delay when either service is interrupted or traffic units cannot depart upon completion of service. Simulation model networks are structured by arranging the individual system operating elements so that the traffic unit flow paths correspond to those of the real system.

Controlled by a monitor routine, this general operating element routine assumes the characteristics necessary to represent each of the many different elements of a network at different times during the simulation. Because of the flexibility of application afforded by this feature, TRANSIM is able to simulate the broad range of complex situations with maximum analytical efficiency in terms of problem set-up, computer running time, and memory storage requirements. [3]

One interesting feature of the TRANSIM system is that, whereas in many analyses it is necessary to take raw data and fit it to an arbitrary distribution, the TRANSIM method uses the input data in the form of histograms. Previous

operating history or other data, as appropriate, can be used directly, without the necessity of re-shaping or forcing the data into a mathematically correct but physically incorrect representation.

II. APPLICATION OF TRANSIM

The TRANSIM method of systems analysis is being evaluated as a management tool for naval shipyards under a contract with the Office of Naval Research. As a part of that evaluation, discussions were conducted with personnel of Puget Sound Naval Shipyard. Several broad areas of problems were discussed, and a specific example was selected after further consultation with members of the Production Department, in particular with the Methods and Standards Section. The example selected is based on the present layout of service areas adjacent to the pierside. An aircraft carrier undergoing routine overhaul (USS RANGER, CVA61, commissioned 10 August 1957) provided the actual data for the example studied.

III. PROBLEM FORMULATION

During the overhaul of an aircraft carrier, approximately six months in length, the ship is drydocked for underwater hull and machinery maintenance, and is later shifted to a shipyard pier berth for completion of overhaul. The example aircraft carrier employed as many as 1500 shipyard workers on board during the overhaul from production shops, plus administrative, design and other personnel. Work study samples indicated that during the periods of heaviest work

loads, travel time expended over all shops accounted for 22% of the man-hours charged to the overhaul of the ship. This travel time can be attributed to many specific reasons, including the obtaining of supplies, drawing or returning tools, personal requirements, and non-productive travel. In particular, a separate analysis conducted by the Methods and Standards Section indicated that tool issue, including transit time, queueing time and other related lost time, would cost in excess of $165,000 during the overhaul. The present system, consisting of a single toolroom with two service windows, located on the pier adjacent to the ship, made it necessary for workers requiring tools to leave the ship, queue at the toolroom and then return to the ship after service.

The study was conducted, therefore, to determine whether alternate toolroom locations on board the ship would reduce the lost time attributed to tool issue sufficiently to make them attractive as a cost reduction device. Specific alternate locations were selected as feasible, these being on the flight deck and/or on the hangar deck. Varied levels of tool support, use of multiple toolroom facilities, and additional servers were considered in order to provide a parametric solution to the manager.

The problem selected is considered to be well-suited to the purpose of demonstrating the feasibility of adapting TRANSIM to shipyard problems because of its simplicity, the availability of adequate data, and the potential savings to the shipyard. Chapter II discusses the present system and

its operation; Chapter III discusses the arrangement of proposed alternate systems and their method of selection; Chapter IV describes the model construction, details and modifications; Chapter V covers the organization of data runs, evaluation and utilization of results; and Chapter VI lists recommendations for improvement and extension of the analysis, and of other areas for possible use of the TRANSIM analysis.

CHAPTER II

PRESENT SYSTEM, DESCRIPTION AND OPERATION

This chapter describes the system in use during the overhaul of the aircraft carrier, and its normal operation. This system covers the normal issuance and return of tools to personnel assigned for routine work to the aircraft carrier during its overhaul.

As shown in Figure 1, the aircraft carrier was moored alongside the pier during the period of data collection. A routine overhaul requires the ship to be drydocked during a substantial portion of the overhaul period; however, the location of toolrooms alongside the ship was considered to be equivalent in both cases (i.e., with equal shipboard populations of workers, and approximately similar distributions of shops, and tool requirements, lost time due to tool issue and associated travel would be similar).

Figure 2 shows an elevation of the aircraft carrier and its subdivision into work areas A, B and C (see page 16). Also shown are the approximate locations of proposed auxiliary toolrooms. Subdivision into work areas was required in order to analyze the distribution of shop personnel, predict the distribution of travel times, and then to predict the effect of the various proposed alternate solutions.

The system of tool issue in use at the time of the study was as follows:

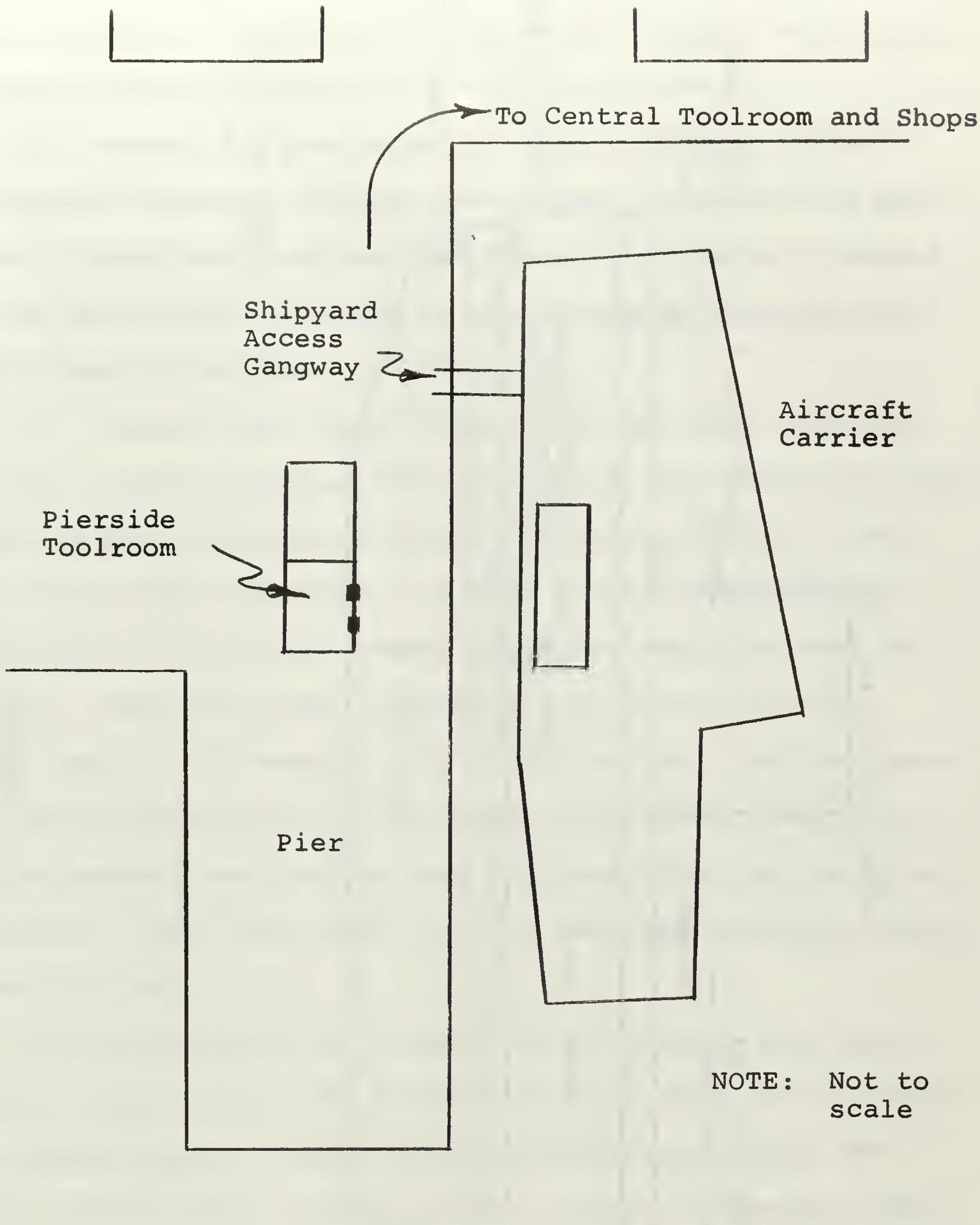


FIGURE 1

PLAN VIEW OF AIRCRAFT CARRIER BERTH
AND TOOLROOM LOCATIONS

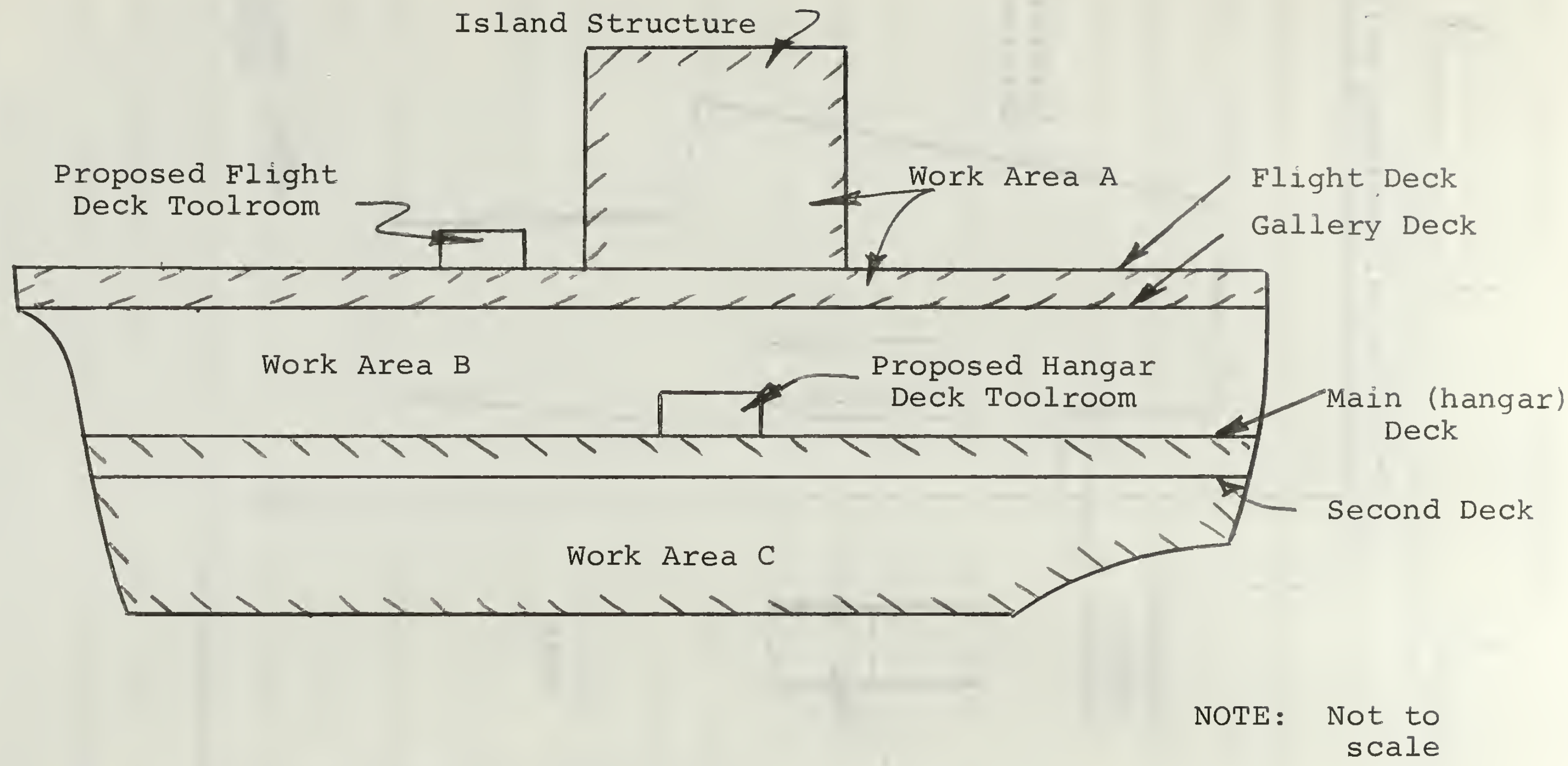


FIGURE 2

WORK AREA SUBDIVISIONS AND PROPOSED AUXILIARY TOOLROOM LOCATIONS

a. One tool-room at pier-side, with two serving windows, providing essentially complete tool issue, replacement, and turn-in facilities.

b. Additional pier-side and shop toolrooms located throughout the yard, serving other piers, drydocks and work areas. These toolrooms may be opened or closed as required by the work level, but when in operation are maintained at stock levels equivalent to (a) above.

c. Central Tool Room, remote from the pier, carrying a larger stock of tools, both in quantity and diversity, than pier and shop toolrooms. Central Tool Room serves as the major tool repair facility, as well as the stock re-order point, and restocks all remote toolrooms daily as required.

d. For each trade, a special tool storage at the "home shop". For example, the Electrical Shop carries special tools applicable only to electricians' work, and also stocks general tools which have high use rates for the electricians. This "home shop" is in a separate building remote from the piers.

When the system is in operation, personnel from many trades report aboard the aircraft carrier prior to the start of working hours. These trade mechanics carry their own tools aboard ship, or keep a small toolbox in storage racks aboard the ship. During the course of the working day, additional tools are required, either to replace worn, dull or broken tools; to supplement the mechanics' own tools; or to perform special tasks. The mechanic then leaves the ship, joins the queue at the pierside toolroom, and draws (or turns

in and draws) the tool required. Approximately 95% of the traffic arriving at the toolroom windows is satisfied at that point, and returns to the work areas aboard the ship. The remaining 5% is not satisfied, and then proceeds either to the Central Toolroom, the home shop toolroom, or other toolrooms in the yard. This small percentage then returns to the ship, after satisfying the tool requirement or determining that it cannot be satisfied at the present time.

CHAPTER III

PROPOSED ALTERNATE SYSTEMS

This chapter discusses proposed alternate tool supply systems, both in alternate locations and in alternate levels of toolroom capacity. A major advantage of a simulation is the testing of alternate systems, to determine the effect of modifying the system without requiring actual real-system modification. In this analysis of shipyard toolroom locations, it was decided to try two alternate locations of toolrooms, two levels of population, and three levels of auxiliary toolroom capacity. Six systems were designed, of which the first was a replication of the original system.

I. TOOLROOM LOCATIONS

A survey of shipboard spaces was made to determine feasible locations of auxiliary toolrooms. Those considered acceptable by the author, in conjunction with shipyard personnel, were (1) on the flight deck, frame 124, abeam of the island structure, (2) on the hangar (main) deck, frame 138, abaft the hangar division doors, and (3) on the second deck, frame 118, centerline (Sick Bay, Ward #2). The third location was eliminated from consideration during later analyses, due to accessibility for tool replenishment, and the requirement to remove installed equipment and build in a tool service area. The other two areas were open deck areas, where portable house structures could easily be placed.

II. POPULATION LEVELS

Two population levels (total number of workers and distribution within shops) were determined in order to test the various alternate systems. The higher level of population is based on an average over a four-week span (five samples available of daily on-board count). The highest four-week average was selected, reflecting an average daily on-board count of 1312 workers in ten major trades, as shown in Table I. The lower level of population is based on an average over the entire period for which data were available, a span of 24 weeks, for which a total of 27 observations were made. The average daily count for these observations was 1058.5 workers (again in the ten major trades).

Usage data were derived at the pierside toolroom to determine the frequency at which personnel of each of the major shops used the toolroom, either to draw or to return tools. No differentiation was made between drawing and returning tools, as the workers frequently exchanged worn tools (i.e., both returned and drew tools at the same time). The toolroom usage data were derived during the middle portion of the working periods of two different days (eliminating the first and last 15 minutes of each four-hour period) due to other data requirements not connected with this study. From this information, and the count of shop personnel on board the ship, a "tool fraction" was derived for each shop, representing the frequency of tool requirements expected for

any other shop population on board. This information is listed in Table II.

Location of personnel on board the ship has a bearing on the amount of time spent in transit to the toolrooms. For this study, the actual locations were not directly available, but an experienced estimate of the distribution was made by shipyard advisors, for each of the shops, into the following major areas:

A: Gallery deck, flight deck and island structure

B: Main deck up to but not including the gallery deck

C: Second deck and below

These estimates of personnel distribution by shops were considered to be most accurate over the period of heaviest population, and are listed in Table III. The major work areas are shown in Figure 2.

From the two sample populations, referred to hereafter as "High" and "Average", a tool usage was derived for each work area. The calculations are shown in Tables IV and V. After review of the actual arrivals throughout the day at the pierside toolroom, it was considered that a poisson arrival rate constant throughout the working period (i.e., characterized by exponential distribution of inter-arrival times, but with no variation of the parameter λ throughout the day) would adequately represent tool requirements. From Tables IV and V, the final poisson mean arrival rates for two levels of population are as follows:

		LEVEL OF POPULATION	
		HIGH	AVERAGE
WORK AREA	A	.514	.416
	B	.165	.126
	C	.523	.431

Arrival rates in personnel per minute generating tool requirements

FIGURE 3 POISSON ARRIVAL RATES

III. TOOLROOM CAPACITY

This term is defined as capability to handle a certain percentage of tool requirements. In the example studied, three levels were considered: 65%, 75%, and 90%. It is assumed that at a 75% stock level, 75% of those personnel requiring tools (and whose location aboard ship makes use of the auxiliary toolroom a logical source of tools) would proceed to that auxiliary toolroom; some will be satisfied, others will proceed to pierside toolroom service, and still others will proceed direct to the Central Toolroom or other tool sources. Similar definitions for the 65% and 90% stock levels are proposed. It was considered that this (the 65-75-90% figures) represented a reasonable range for the toolroom capacity; it would be unreasonable to design a system that could not serve at least two-thirds of the potential customers, and on the other hand it did not seem feasible to build an auxiliary toolroom with the same capacity as the pierside facilities, and still be able to make it

easily transportable. In Chapter VI are discussed some further extensions of analyses which apply to this phase of the problem.

IV. ALTERNATE SYSTEMS

Six alternate systems were developed (including as one variant the original system) which were to be tested as possible modes of operation of tool support for the overhaul. Details of each system are listed below.

System I

System I, the original system as operating during the period of data collection, consists of one toolroom on the pier, with two service windows in operation. The stock level at the toolroom is 95%. All personnel requiring tools report to this toolroom; 95% are satisfied and return to the work areas aboard ship, and the other 5% then go to the Central Toolroom, shop toolrooms, or other toolrooms located throughout the yard to obtain required tools, before returning to the ship.

System II

System II consists of (a) the pierside toolroom and (b) an auxiliary toolroom on the main (hangar) deck of the ship. Each of the toolrooms has a single service window. The pierside toolroom has the same stock level as in System I, and the same distribution of personnel from output. The main deck toolroom has a 75% stock level, and 75% of all personnel requiring tools report there. Of those attempting to draw tools at the main deck toolroom, 90% are satisfied;

of the remaining 10%, 8% go to the pierside toolroom for service and 2% go to Central Toolroom or other off-pier sources.

System III

System III consists of (a) the pierside toolroom and (b) an auxiliary toolroom on the flight deck of the ship. Each of the toolrooms has a single service window. The system is the same as System II, except that the on-board toolroom receives 75% of those personnel in Work Area A, and 25% of those in Work Area B. All other personnel go to the pierside toolroom first, either because of convenience or because the required tools are not normally stocked aboard.

System IV

System IV is a combination of Systems II and III, and consists of (a) the pierside toolroom, (b) an auxiliary toolroom on the main deck, and (c) an auxiliary toolroom on the flight deck. All three toolrooms have single service windows. Both of the on-board toolrooms are considered at 75% of tool capacity; the flight-deck toolroom receives 75% of the personnel from Work Area A, and the main-deck toolroom receives 75% of those from Work Areas B and C. From the flight-deck toolroom, 90% return to work, 4% go to the main-deck toolroom, 4% go to the pier toolroom, and 2% go to the Central Toolroom. From the main-deck toolroom, 90% return to work, 8% to the pier toolroom, and 2% to the Central Toolroom, as in System II.

System V

System V is a modification of System II, in which a second service window is in operation in the main-deck toolroom; the pierside toolroom is maintained at a single-window capacity. Output to other elements of the system is the same as in System II.

System VI

System VI is a modification of System III, in which a second service window is in operation in the flight-deck toolroom; otherwise the system is the same as in System III.

CHAPTER IV

MODEL CONSTRUCTION AND DETAILS

This chapter describes the construction of the computer models of the tool issue systems, first in terms of the present system, and then in terms of the proposed alternate systems. All systems were reduced to a common system with varied operating hours for particular operating elements, and varied distributions of outputs from the operating elements, in order to simplify the computer runs. A discussion is included of the data input to the model runs, and also of the artificialities introduced in the model in order to more closely simulate actual working conditions.

I. MODEL OF PRESENT SYSTEM

A model of the present system is shown in Figure 4. The key describes the standard symbolic representation of the various elements in the model. Traffic units (as described in Pages 9 and 10) are used to represent individual workers who require tools. The three work area sources of traffic units are used to differentiate the transit times between various work areas and the toolrooms. A single toolroom queue is represented as a reasonable modeling of reality; two queues are normally formed, but if one window is not occupied by a "customer", and the other window queue (exclusive of the customer in service) has anyone waiting for service, at least one customer shifts to the vacant window. After queueing and service, 95% of the output

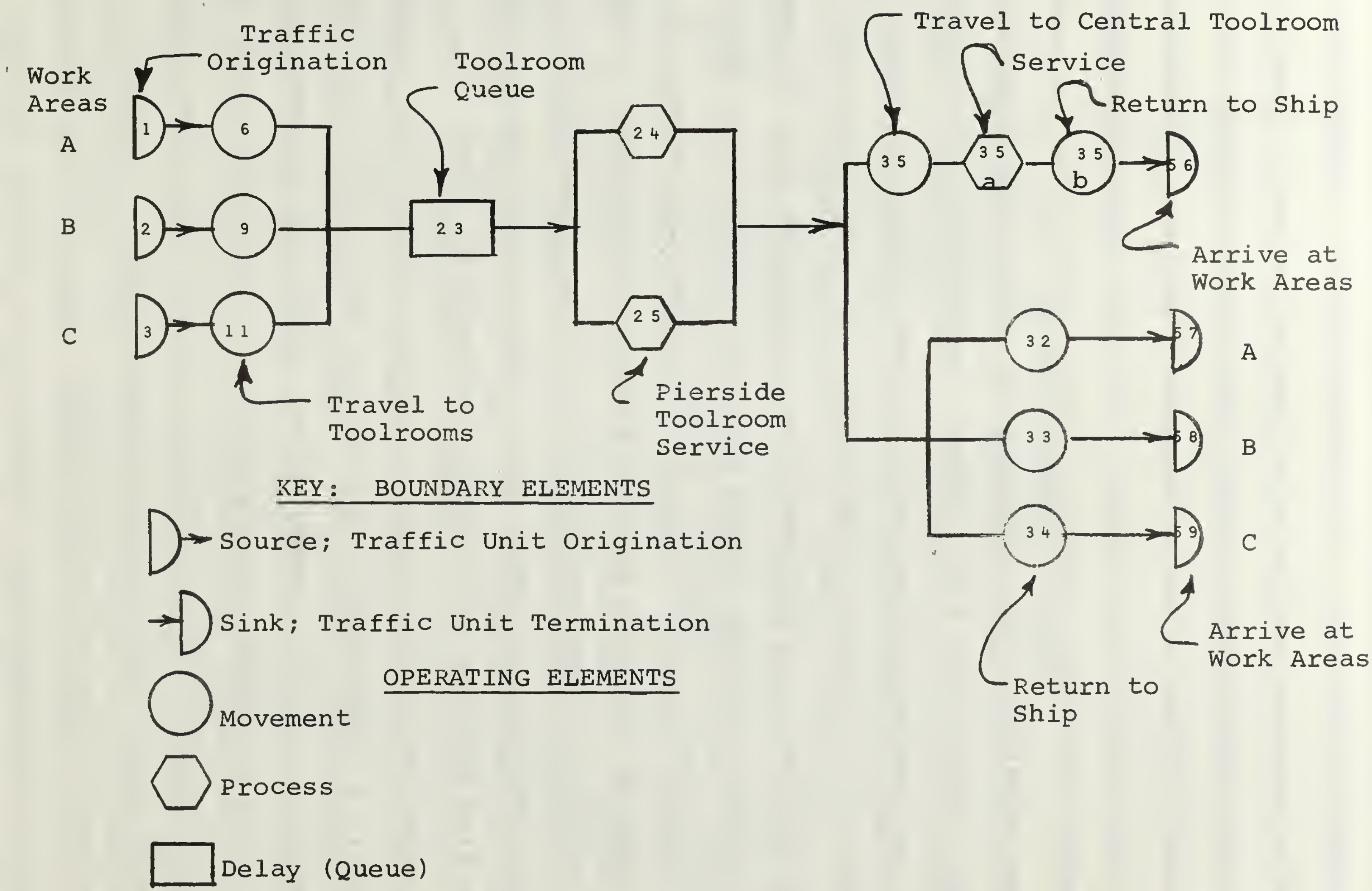


FIGURE 4

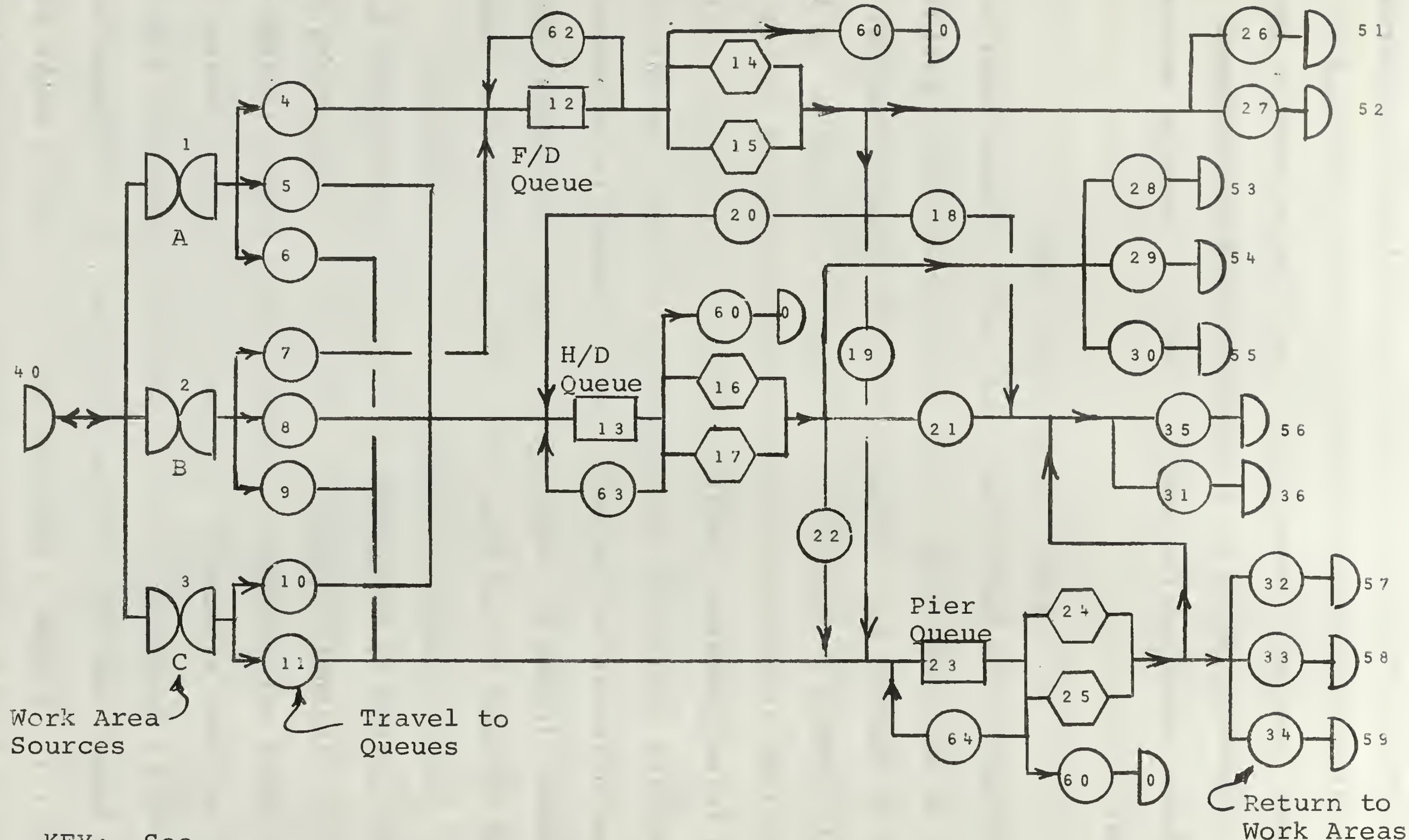
MODEL OF PRESENT TOOL ISSUE SYSTEM

traffic units are returned to the work areas; the other 5% are channelled to Central Toolroom or other service prior to return to the ship. The source boundary elements are used to generate traffic units from Work Areas A, B and C in accordance with the arrival rates shown in Figure 3. The sink boundary elements represent the return of workers to their assigned work areas. The travel operating elements represent the time consumed in travel to and from the queues; these travel times are different for each of the general work areas, but are (for each workman) the same for both leaving for, and returning from, the toolrooms. Thus, by keeping track of the identity of the workman (as coming from Work Area A, B, or C), his travel time is selected from the same distribution for both travel operating elements; and these distributions are different for the three work areas. In the case of travel to and from the Central Toolroom, it was not considered necessary to differentiate between workers of different source areas, as the total travel time and service time would be only slightly affected by source area, in comparison to total travel time and service. The toolroom queue is a single queue, as discussed above, with unlimited capacity -- that is, queues of any length can be accommodated -- and no unusual queue discipline is specified, such as priority classifications; it is a simple "First Come, First Served" queue. The toolroom windows operate in parallel, each with a capacity of one customer, and with the same service time distributions. Service at the Central Toolroom is handled differently, in that no queue is built up; this

is due to the larger service capacity of the Central Toolroom. However, the service time distribution is different to that of the pierside toolrooms, as it is also used to represent that small fraction of people whose service extends to several hours -- a reasonable and not uncommon event when searching for special tools or checking several sources.

II. MODEL OF COMPLETE SYSTEM

Following the method described above, models were designed to represent each of the proposed alternate systems listed in Chapter III. These were then brought together into a single common system, which is shown in Figure 5. It is evident from inspection that the entire system is not designed to be operated simultaneously, as a total of six toolroom service facilities are provided, on board the ship or on the pier adjacent to the ship. As discussed in Reference 1, Data Sheets (Forms E) were completed for the original system modeled (System I, see Page 59), and are included in Appendix B. Also included in Appendix B are the additional changes applied to the model to change it successively to the other alternate systems. In general, the operating rules of the model were changed, from the basic system (System I) to any proposed alternate, by opening or closing service windows, and by changing the distribution of personnel from the source areas, and from the service areas, as discussed in Chapter III. System I operates with all traffic units generated going to the pierside toolroom; there are no units



KEY: See Figure 3

FIGURE 5

MODEL OF COMPLETE SYSTEM

directed to the ship service facilities, and service windows (Elements 14 through 17) are closed throughout the simulation period. For System II, Operating Element 17 is opened, and Operating Element 25 is closed, for the test run; and the distribution of workers from all three work areas to the two available service windows is changed -- 75% of the workers from all three areas initially go to window 17 (on board the ship, on the hangar deck). Similar changes are instituted by the modifications shown in Appendix A to test the various proposed alternate systems.

Some model details are of interest to show the technique of simulating the operation of the actual system. For example, the toolrooms do not normally operate during the regularly scheduled lunch periods (1200-1230 hours). While some personnel may be waiting in line to draw tools, it is necessary that they (1) be scheduled for the half-hour lunch break; (2) return to the line at 1230 in order of priority as previously established before the window closed; and (3) their time during the lunch break not be charged to queueing time. For this purpose a dummy element was introduced at each queue which opened at 1200, with unlimited capacity, with a constant service time of thirty minutes, and a return of traffic units to the queue at the end of that service time. Thus time in the queue elements did not include this period of lost time. Similarly, at the end of the day, it was necessary to clear the queues. This was accomplished by establishing the dummy Operating Element 60, which opened at 1625 and cleared the queues.

Generation of the traffic units was accomplished by establishing a single generator, Operating Element 40, which generates three types of traffic units; these are delivered to Elements 1, 2 and 3 respectively (Work Area A, B and C), where they are converted to (1) outgoing traffic units (workers requiring tools) and (2) return units going to Element 40, continuing the process of traffic unit generation.

III. MODEL INPUT DATA

Model input data include travel times to and from various work areas and tool service points; tool service times, both in the auxiliary toolrooms, the Central Toolroom, shop toolrooms, and outlying toolrooms; operating hours of various facilities; operating hours for traffic generation; queue disciplines; distribution of output traffic from various operating elements; and traffic generation rates. These data are discussed in detail below.

Travel Times

Travel times were developed from each work area to each toolroom location, including the Central Toolroom. In general, actual transit times were taken by stopwatch using shipyard personnel, transiting during normal working hours under normal traffic conditions. Work Area A, for example, comprises working locations from the forward end of the flight deck, to the after end, to the top of the island structure, to the Combat Intelligence Center complex on the Gallery Deck amidships. From typical work locations, including the most remote and the nearest working locations, times

were observed to the pierside toolroom, to the hangar deck toolroom (hypothetical), and to the flight deck toolroom (hypothetical), etc. This gave minimum and maximum travel times from Work Area A to the locations required for simulation of traffic movement. Since the distribution of workers within the broad Work Areas was not further broken down, it was considered that a simple uniform distribution between minimum and maximum would give adequate representation of the traffic for this model, and was therefore selected. Then, for each worker generated in Work Area A, and transitting to the pierside toolroom, a random number was generated, and a travel time selected between the minimum and maximum travel times established for that travel route. Each travel route is shown in one of the tables (Tables VI through XVI) in the Appendix. For the return trip, a similar travel time selection was made.

Tool Service Times

Tool service times were based on observation of the actual service times in the pierside toolroom, and an estimate of the same service times in the Central Toolroom and other remote service areas. For the pierside toolroom, it was considered that the minimum service time for tool issue/turn-in was one minute; that 50% were completed in 1.75 minutes; and that 100% were completed in 3.0 minutes. Between these fixed points, simple linear interpolation was considered sufficiently accurate as a representation of service times. A random number was generated and the service time was then selected from the cumulative distribution shown

in Table XVIII. As the proposed toolrooms aboard the ship are hypothetical, it was necessary to estimate their service times; these were considered to be the same as the pierside toolroom as an adequate representation. For the Central Toolroom and other service areas, service time was developed to include travel time from the pierside toolroom to the Central Toolroom, service at the Central Toolroom, and return to the shipboard work areas. A minimum time of 15 minutes was considered representative of the time required for this service (this included one minute of actual issue counter service); 50% were estimated to be completed in 16 minutes (2 minutes counter service time); 95% completed in 19 minutes (5 minutes counter service time); and 100% were completed in 120 minutes (accounting for search through several shops or other service areas). Between these points, again a simple linear interpolation was considered sufficiently accurate to represent expected service times, and random generation of service times was performed as above.

Operating Hours of Facilities

Operating hours of toolrooms were as specified in the shipyard operations. Shipboard and pierside toolrooms were considered to be in operation from 0800 to 1200, and from 1230 to 1630. The Central Toolroom and remote facilities operating hours were simplified to be open from 0800 to 1630, as not much traffic was expected there, and personnel at those facilities would be expected to continue through the normal lunch break periods in order to return to shipboard work areas as soon as possible. If traffic was observed to

be inordinately heavy at remote areas, and this simplification appeared to be substantially affecting the results, this would require further investigation, but in the simulation runs this simplification appeared to be insignificant.

Operating Hours for Traffic Generation

The data collected at the pierside toolroom to determine tool usage was developed during the 3.5 hours from 0815 to 1145, or from 1245 to 1615; that is, it was sufficiently remote from starting and quitting times (considering the short window service times) that the traffic generation figures shown in Figure 3 should not be affected by any tendency to postpone tool requirements until the start of the next work period. However, in operating the model it was considered necessary to start generating traffic at 0800 for each simulation, and to stop at 1130; and again in the afternoon periods to start at 1230 and stop at 1600. This is considered a realistic representation of the tendency to postpone such requirements; and of the tendency for the tool lines to dwindle prior to quitting times.

Queue Disciplines

All queues are considered of infinite capacity, and there is no requirement for people to look at the queue length and go to alternate facilities rather than wait for service. While this may be unrealistic in the actual case, it was considered necessary in order to examine the effect of the proposed alternate systems as the toolrooms operated at near capacity. Similarly, there is not (in this case) any arrangement to operate variable numbers of service

windows to meet capacity requirements. The queues operate on a simple "first come, first served" basis with no priority class of service, and with no variation of service time dependent upon queue length.

Distribution of Output Traffic

Output traffic from many elements in the models is subject to distribution to more than one path of following elements. For example, traffic from Element 1 (Work Area A) goes to the hangar deck toolroom (75%) or to the pierside toolroom (25%) in Systems II and V. As each traffic unit is generated at Element 1, a random number is selected, and its destination is then determined (from that random number) as either Element 5 or Element 6. This distribution of 75 to 25 is a factor to be considered in stocking the toolrooms to meet such a traffic distribution. However, the output from a toolroom service window is based on estimates of the effectiveness of the toolroom service, and of probable traffic distribution of unsatisfied customers. Shipboard toolrooms are estimated to be 90% effective in satisfying the requirements of those people getting to the windows; of the remaining 10%, 2% are considered to go to the Central Toolroom, and the others either to another shipboard toolroom (System IV) or to the pierside toolroom. Distribution of these customers is by Monte Carlo simulation, as above.

Traffic Generation Rates

Traffic generation rates used as inputs to the models are composed of "High" and "Average" populations, developed

as shown in Chapter III. These generation rates are applied during the times specified in Operating Hours for Traffic Generation, above.

CHAPTER V

DATA RUNS AND RESULTS

This chapter discusses the organization of the data runs as made with the models described, and the evaluation of the data derived from these runs. It further discusses the utilization of these results in the operation of the shipyard.

I. ORGANIZATION OF DATA RUNS

A minimum of fourteen runs were required to evaluate the various systems. These were organized as shown in Figure 6, below.

Run No.	System	Population	Aux T/R Capacity
1	I	High	N.A.
2	II	"	75%
3	III	"	"
4	IV	"	"
5	V	"	"
6	VI	"	"
7	I	Average	N.A.
8	II	"	75%
9	IV	"	"
10	V	"	"
11	IIA	High	90%
12	VA	"	"
13	IIB	"	65%
14	VB	"	"

FIGURE 6

INPUT FOR DATA RUNS: ALTERNATE SYSTEMS, POPULATION LEVELS AND TOOLROOM CAPACITIES

From the data derived from runs 1 through 6, the present system (System I) can be compared at the High population level with all other systems at the Auxiliary toolroom capacity level of 75%. From runs 7 through 10, the same comparison can be made for three of the five alternate systems (those

considered to be most feasible prior to the analysis), with the population at the Average level. From runs 1, 2, 5 and 11 through 14, the present system can be compared with two proposed alternates, Systems II and V, at three levels of auxiliary toolroom support capacity. The systems are labeled with suffixes A and B due to minor modifications in the input and output distributions of customers at the auxiliary toolrooms; otherwise they are identical to the parent systems II and V.

II. EVALUATION OF RESULTS

In this analysis, the measure of effectiveness selected for evaluating the various systems was the total time consumed in transit to and from the toolrooms, queueing, and service time at the windows. The data return from the TRANSIM system is designed to produce the total time of processing through the various elements, which provided the data required directly in usable form. The original system, System I, was running near capacity, as indicated by the arrival rate of 1.2 per minute and a mean service rate of 1.88 per minute; if a proposed alternate system were to prove unworkable, at the population levels tested, it showed in the rapid buildup to long queues, which were considered in the analysis to be unlimited in length during the data runs. Presentation of data on these unlimited-length queues is not of practical interest, and the systems are considered to be not in balance, and unsatisfactory as actual systems. If the actual queue length could be considered as an input to the selection process

(that is, if the queue were over a specified length, all arriving customers would transit to alternate service facilities) the systems defined as unsatisfactory in the first analysis might still be workable, and in fact might prove to be the best overall. This is discussed at greater length in the next chapter.

Figure 7 below summarizes the results extracted from Table XXI in Appendix C.

System	Population Level	Total Customers	Walking Time	Queueing Time	Total Time
I	High	530	108.1	201.1	309.2
IV	"	462	62.5	20.2	82.7
V	"	523	76.9	21.3	98.2
VA	"	419	52.7	14.9	67.6
VB	"	519	79.2	37.7	116.9
I	Average	405	86.3	18.1	104.4
IV	"	406	51.0	14.6	65.6
V	"	380	48.5	5.4	53.9

FIGURE 7

SUMMARY OF TOTAL TIME EXPENDED IN TRANSIT AND QUEUEING, IN MAN-HOURS

The data output for the systems, as summarized in Figure 7, showed the following general results. First, at the high level of population, only Systems I, IV, and V were acceptable; the other systems were not in balance. Second, at the average level of population, as would be expected, Systems I, IV, and V were still workable, with substantially less lost time; but System II was still not workable. (As stated in Section I of this chapter, Systems III and VI were not tested at this population level.) The examination of variation of tool level support (Systems IIA, IIB, VA, and

VB) showed that these variations were also reflected in the total time expenditure; and that System II could not be brought into an acceptable system balance by varying this factor within the range of 65 to 90 percent.

III. UTILIZATION OF RESULTS

From Figure 7 it can be concluded that the installation of System IV would save 226.5 man-hours per day at the high level of population, and 38.8 man-hours per day at the average level. System V would save 211.0 man-hours per day at the high level, and 50.5 man-hours per day at the average level. For planning, figures of man-hour cost run from $7.20 to $8.40, varying with the shop. This indicates that at the high level of population (effectively, over at least six to eight weeks), if the toolrooms could be operated at a cost of less than about $1700 per day, including stock costs, building costs, direct labor and overhead costs, they would be feasible as a cost-reduction device.

From an extension of the analysis, as proposed in the next chapter, a more precise population level could be determined at which point the selected system should be placed in operation; and further, a selection of alternate controls on opening additional service windows could be devised.

The discussion above is based on the assumption that the single data runs made for each system represent mean expected values, and can be used to make analytical evaluation of competitive systems. The next chapter discusses this

point more fully in the section on refinements. Since System I was designed to resemble closely the system as now in operation, it is of interest to compare them. The following figure shows such a comparison:

System	Total Customers	Time, Walking	Time, Queueing	Time, Total
I	405	86.3	18.1	104.4
Actual	385	57.7	38.5	96.2

FIGURE 8

COMPARISON OF SIMULATED AND ACTUAL SYSTEMS
(TIME IN MAN-HOURS)

The data shown for System I are those shown in Figure 7 for the average level of population. Those shown for the actual system were provided by the shipyard in a preliminary analysis. Another comparison was made using work samples of the various shops concerned. Analysis of productive travel (which includes, but is not limited to, travel for tools) showed that for nine of the ten shops considered (data not available for Shop 64), during a three-day period of the peak employment population, the average time ran from 8.6 to 13.2 percent of total man-hours, expended in productive travel. The simulation runs for System I indicated that from 1.6 to 2.6 percent of total time was expended on travel for tools; and including queueing time this ran from 3.2 to 7.3 percent. A further comparison, that of the queueing time for System I, showed sample queueing times from 0 to 10.1 minutes, with an average of 2.7 minutes, compared to an actual system sample of 0.55 to 17.4 minutes, with an average of 5.8 minutes. The comparison is closer than is

apparent, as the data for the actual system includes service time, whereas the data for simulation is for queueing time only. All of these comparisons indicate that the simulated system is a reasonably accurate representation of the actual system, both for travel and queueing time.

CHAPTER VI

RECOMMENDATIONS

This chapter discusses recommendations under three categories: first, those which would refine the solution of the presently proposed problem; second, those which extend the solution to a broader group of problems, still closely tied to the issue of tools and supplies aboard a ship; and finally, other problems not tied to the basic problem, but which appear to be useful areas for application of the techniques of TRANSIM within the shipyard management purview.

I. REFINEMENTS

Extended Data Runs

The first refinement recommended is merely the use of extended data runs to obtain a statistically satisfying result for each of the systems already run. Due to limited computer operating time and funds, only one run was made on each system; it is advisable to make enough runs so that a mean result can be obtained, and a better idea of the maximum variation from that mean. In the analyses run herein, it was necessary for the sake of the example to assume that the first run on each system was an acceptable representation of the mean for that system. That it was not is evident from the wide spread of tool requirements generated from supposedly identical populations (see Column 3 of Figure 7). It would be relatively simple to operate each system for several runs until the cumulative means of population and total times achieved an acceptable steady-state solution.

Queue Selection as a Function of Queue Length

Section II of Chapter V indicates that several systems were considered "not in balance" due to excessive length. In the actual case, if such a system were installed, a workman would go to the "normal" queue, take a look at the length of the line, and then go to the alternate tool windows on the pier or elsewhere as appropriate. A natural extension of the model would then incorporate a maximum length of queue, with alternate routing instructions applicable when the queue was filled. This would make some of the proposed systems workable which are now out of balance, and could show acceptable a less costly system than those now proposed. (For example, System II with this alternate routing should deliver about the same saving in walking time at considerably less cost in overall toolroom investment than System IV, and less cost in toolroom attendants than both Systems IV and V.)

Operating Hours as a Function of Queue Length

Another possibility for alternate systems is the use of queue length as an input to operating hours. That is, if for example the queue of System II exceeded a certain set length, a second window (operating element 16 in this case) opens, and remains open either until the queue length goes to zero, or to the end of the working period as desired. In effect the systems shifts from II to V. This assumes a certain flexibility in the toolroom manning level, which could be tested for its value by the manager, using the simulation techniques.

Refinement of Personnel Distribution

Distribution of personnel throughout the ship obviously has an effect on the total time consumed in transit; it also affects the tools required, from the boiler rooms to the catapult spaces, and the frequency with which they are needed. The division of the ship into three broad areas, and distribution of personnel within those areas, is discussed in Section II of Chapter III. A refinement of the solution which might prove to be useful would be a finer subdivision of the ship into more work areas; a distribution of personnel of each major shop within these areas; and perhaps even a variation in tool requirements for personnel from the same shop who are located in different work areas. The general model described in Chapter IV was originally designed to take into account the distribution of shop personnel in the three areas (a total of 25 groups of personnel spread over the three areas; see Table III). This was considered an unnecessary refinement for the first analysis, but is merely a step in the direction of the refinement proposed herein. In the analysis of cost, where man-hour cost varies with shop, this factor may be significant; however, the simulation technique would allow an inexpensive analysis to determine whether such refinement is of value.

Variation of Population Level

A broader spread of population should be treated, to determine the economical population level at which the proposed alternate system should be installed, removed, or

altered. This is a relatively simple and clear analysis once the cost of operation of such systems is determined.

II. EXTENSIONS

Toolroom Capacity

Toolroom capacity was defined as "capability to handle a certain percentage of tool requirements" generated aboard the ship. The first extension of this problem is to determine what tools are required to meet this definition. It is obvious that any number of mixes could be determined, each of which would satisfy the same percentage of tool requirements; it remains to select that mix, of those proposed, which is the lowest cost, in terms of inventory, space and other costs. It is evident that experience may dictate other measures than pure cost in selecting the proper tool mixes for the auxiliary toolrooms, including ease of restocking, maximum sizes of tools, pilferage problems, etc. Different stock levels of different tools would be determined as acceptable alternates, and in the systems including toolrooms on both the flight deck and hangar deck (System IV and variations thereon) different mixes of tools could be determined to service the differing requirements.

Extra Capacity

The advisability of building extra capacity into the systems could be investigated. For example, the cost of building in a two-window capacity should be analyzed, even for the single-window systems. The capacity which is then available should be determined, and its cost. In periods of

unscheduled high-load usage (crash programming with overtime labor, for example) the tool system could then support the additional labor load. This is another form of insurance, and is subject to the same kind of cost-benefit analysis.

Tool "Runners"

In the operation of the tool issue system, one of the underlying assumptions is that the man requiring the tools leaves his work area and draws the tools. The validity of this assumption should be tested against an alternate system using "runners" to handle the unskilled work of drawing and delivering tools to the work area. Such a system, perhaps using telephone calls to submit requisitions, runners drawing and carrying the tools to the workman, and taking care of the necessary paperwork, might satisfy the tool issue problem at lower overall cost. This type of approach could be easily tested in simulation, and results verified in operation.

Shop Stores

Another extension of the system is the study of the "shop stores" requirements. In addition to tools, the trade mechanics are frequently required to leave the work areas to obtain stores, such as electrical fittings, welding supplies, piping and fittings, etc. The location and management of these shop stores issuing facilities parallels the problem of tool issue, and would prove to be equally useful as an area of cost analysis.

III. OTHER PROBLEMS

Other areas which appear to be feasible for the use of the TRANSIM approach to analysis include the following:

1. Material problems: material ordering and repair scheduling, selection of optimum sources, etc.; material handling methods; material inspection methods.

2. Personnel problems: manpower staffing problems, such as optimum size of rigger gangs and other service crews; location and design of personnel service facilities.

3. Network problems: information flow systems; review of PERT-type systems analyses from a probabilistic standpoint; shipyard scheduling of overhaul and repairs; design evaluations of multiple-purpose buildings by analysis of information flow, and personnel flow within the proposed alternate designs.

BIBLIOGRAPHY

1. TRANSIM - General Purpose Transportation System Simulator, User's Manual. Project TRANSIM, Department of Engineering, University of California, Los Angeles. Report No. 66-6, May 1966.

2. Feiler, A. M. Simulation Analysis of the Marine Port-Complex. Project TRANSIM, Department of Engineering, University of California, Los Angeles. Report No. 66-12, October 1966.

3. Feiler, A. M. Simulation Analysis of the Marine Port-Complex (Project TRANSIM, Department of Engineering, University of California, Los Angeles, Report No. 66-12, 1966), pp. 5-8.

APPENDIX A

Shop \ Week	1	2	3	4	5	Average
11	147	144	142	143	137	142.6
26	221	205	216	221	213	215.2
17	64	65	76	76	77	71.6
41	64	60	58	61	62	61.0
56	210	216	218	234	234	222.4
38	178	176	178	194	217	188.6
51	175	177	189	171	171	176.6
64	53	42	48	50	50	48.6
71	52	43	46	55	58	50.8
72	130	137	127	137	142	134.6
TOTAL	1294	1265	1298	1342	1361	1312.0

TABLE I

SHIPBOARD POPULATION, BY SHOPS,
PEAK EMPLOYMENT ON CVA OVERHAUL

SHOP	TOOL ROOM USAGE	AVG. ON-BOARD COUNT	TOOL FRACTION
11	107	108.7	.788
26	91	136.7	.533
17	43	67.7	.508
41	20	55.7	.287
56	63	234.3	.215
38	112	187.0	.479
51	39	142.3	.219
64	19	33.7	.452
71	4	39.7	.081
72	18	92.7	.155

TABLE II

TOOL FRACTION, BY SHOPS

NOTE: Toolroom usage records number of personnel for each shop over a period of 8-3/4 hours over two days. The average on-board count is an estimate of the actual number on-board during the toolroom sampling. "Tool fraction" is the expected number of toolroom calls per man on board per seven-hour period of toolroom requirements.

Shop \ Area	A	B	C
11	25	25	50
26	25	25	50
17	95		5
41	5	5	90
56	50		50
38	50		50
51	60	20	20
64	90	10	
71	30	40	30
72	50		50

TABLE III

PERCENTAGE DISTRIBUTION OF SHOP PERSONNEL
BY SHIPBOARD WORK AREAS

	Work Area A			Work Area B			Work Area C		
Shop	No. Assigned	Tool Fraction	Tool Calls	No. Assigned	Tool Fraction	Tool Calls	No. Assigned	Tool Fraction	Tool Calls
11	35.65	.788	28.09	35.65	.788	28.09	71.30	.788	56.18
26	53.80	.533	28.68	53.80	.533	28.68	107.60	.533	57.36
17	68.02	.508	34.55	0		0	3.58	.508	1.82
41	3.05	.287	0.88	3.05	.287	0.88	54.90	.287	15.76
56	111.20	.215	23.91	0		0	111.20	.215	23.91
38	94.30	.479	45.17	0		0	94.30	.479	45.17
51	105.96	.219	23.21	35.32	.219	7.74	35.32	.219	7.74
64	43.74	.452	19.77	4.86	.452	2.20	0		0
71	15.24	.081	1.23	20.32	.081	1.65	15.24	.081	1.23
72	67.30	.155	10.43	0		0	67.30	.155	10.43
TOTALS	598.26		215.92	153.00		69.24	560.74		219.60

TABLE IV

TOOL REQUIREMENTS BY WORK AREA, HIGH POPULATION

	Work Area A			Work Area B			Work Area C		
Shop	No. Assigned	Tool Fraction	Tool Calls	No. Assigned	Tool Fraction	Tool Calls	No. Assigned	Tool Fraction	Tool Calls
11	29.70	.788	23.40	29.69	.788	23.40	59.39	.788	46.80
26	38.55	.533	20.55	38.56	.533	20.55	77.11	.533	41.10
17	52.35	.508	26.59	0		0	2.76	.508	1.40
41	2.76	.287	0.79	2.76	.287	0.79	49.81	.287	14.30
56	85.93	.215	18.47	0		0	85.92	.215	18.47
38	89.61	.479	42.92	0		0	89.61	.479	42.92
51	74.33	.219	16.28	24.78	.219	5.43	24.78	.219	5.43
64	32.70	.452	14.78	3.63	.452	1.64	0		0
71	10.81	.081	0.88	14.42	.081	1.17	10.81	.081	0.88
72	63.85	.155	9.90	0		0	63.85	.155	9.90
TOTALS	470.59		174.56	113.84		52.98	464.04		181.20

TABLE V

TOOL REQUIREMENTS BY WORK AREA, AVERAGE POPULATION

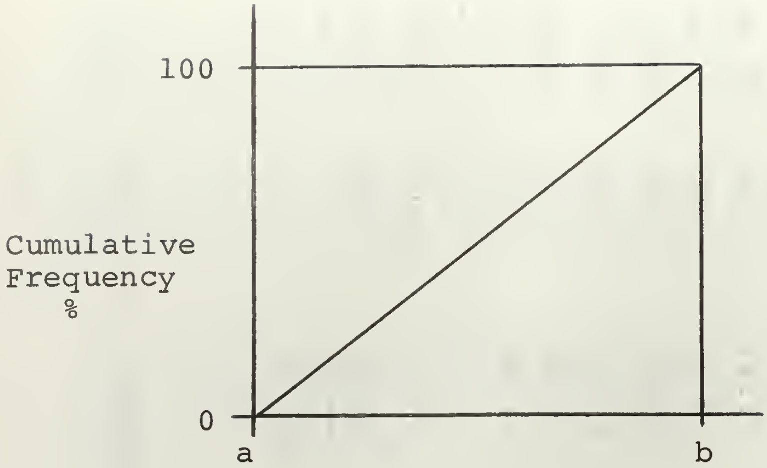


TABLE	a, minutes	b, minutes	Remarks
VI	1.3	4.0	AREA A to F/D Toolroom
VII	2.5	4.5	" " " H/D "
VIII	5.0	8.0	" " " PIER "
IX	1.5	4.5	" B " F/D "
X	1.0	4.0	" " " H/D "
XI	2.0	7.0	" " " PIER "
XII	2.0	5.0	" C " H/D "
XIII	4.5	7.5	" " " PIER "
XIV	4.0	5.0	F/D Toolroom to PIER Toolroom
XV	1.5	3.0	" " " H/D "
XVI	2.0	2.5	H/D " " PIER "

TABLES VI THROUGH XVI

DISTRIBUTION OF TRAVEL TIMES

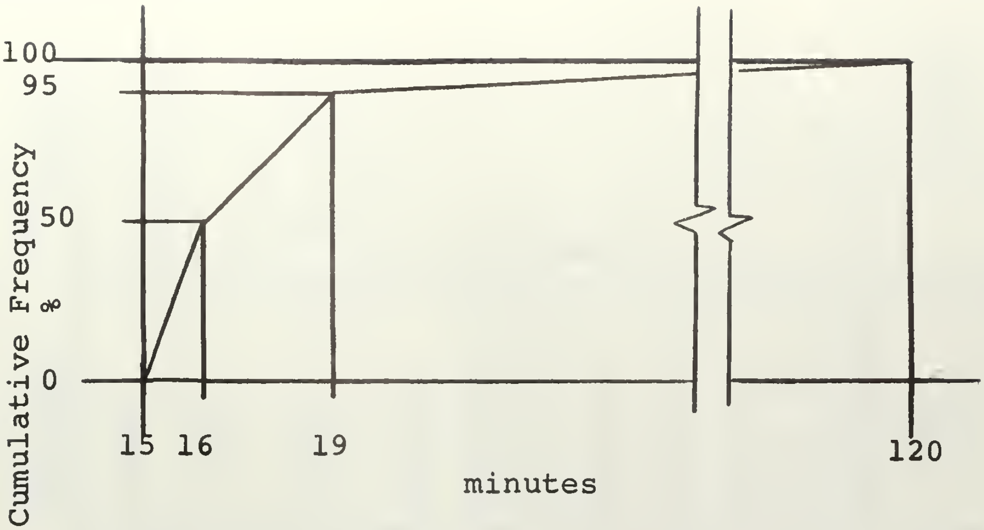


TABLE XVII

DISTRIBUTION OF SERVICE TIME, CENTRAL TOOLROOM

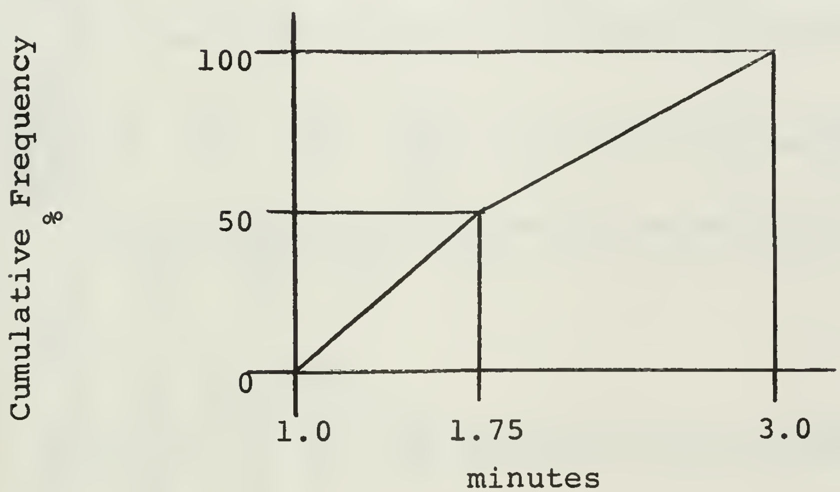


TABLE XVIII

DISTRIBUTION OF SERVICE TIME, ALL OTHER TOOLROOMS

APPENDIX B

SOE	TRAFFIC UNIT TYPE	T/U CONV. RULE	ELEMENT CAPACITY	DELAY ACCOM	OPERATING SCHEDULE	SERVICE TIME REF.	SUCCESSOR ELEMENT
1	101-110	101-110 $\xrightarrow{s}$ 201-210 + 1-10	NA	NA	Open 0800-1130 1230-1600	NONE	1- 10: 6 201-210: 40
2	111-116	111-116 $\xrightarrow{s}$ 211-216 + 11-16	NA	NA	Open 0800-1130 1230-1600	NONE	11- 16: 9 211-216: 40
3	117-125	117-125 $\xrightarrow{s}$ 217-225 + 17-25	NA	NA	Open 0800-1130 1230-1600	NONE	17- 25: 11 217-225: 40
4	1-10	NONE	UNLIM	NO	Always Open	Table VI	12
5	1-10					Table VII	13
6	1-10					Table VIII	23
7	11-16					Table IX	12
8	11-16					Table X	13
9	11-16					Table XI	23
10	17-25					Table XII	13
11	17-25					Table XIII	23
12	1-16	NONE	UNLIM	YES	Open 0800-1200 1230-1630	NONE	14,15,60 or 62
13	All		UNLIM	YES	Open 0800-1200 1230-1630	NONE	16,17,60 or 63

TABLE XIX

FORM E FOR SYSTEM I

SOE	TRAFFIC UNIT TYPE	T/U CONV. RULE	ELEMENT CAPACITY	DELAY ACCOM	OPERATING SCHEDULE	SERVICE TIME REF.	SUCCESSOR ELEMENT
14	1-16	NONE	1	NO	Closed	Table XVIII	NONE
15	Same as 14						
16	All		1	NO	Closed	Table XVIII	NONE
17	Same as 16						
18	1-16		UNLIM	NO	Always Open	Table XIV	31 or 35 All
19	1-16					Table XIV	23 All
20	1-16					Table XV	13 All
21	All					Table XVI	31 or 35 All
22	All					Table XVI	23 All
23	All			YES	Open 0800-1200 1230-1630	NONE	24,25,60 or 64
24	All		1	NO	Open 0800-1200 1230-1630	Table XVIII	All: 5% 31 or 35 T/U 1-10: 95% 32 11-16: 95% 33 17-25: 95% 34
25	Same as 24						

TABLE XIX (Continued)

SOE	TRAFFIC UNIT TYPE	T/U CONV. RULE	ELEMENT CAPACITY	DELAY ACCOM	OPERATING SCHEDULE	SERVICE TIME REF.	SUCCESSOR ELEMENT
26	1-10	NONE	UNLIM	NO	Always Open	Table VI	All: 51
27	11-16					Table IX	All: 52
28	1-10					Table VII	All: 53
29	11-16					Table X	All: 54
30	17-25					Table XII	All: 55
31	All				Open 1615-1645	NONE	All: 36
32	1-10				Always Open	Table VIII	All: 57
33	11-16					Table XI	All: 58
34	17-25					Table XIII	All: 59
35	All				Open 0800-1615 1900-2200	Table XVII	All: 56
40	201 thru 225	$201 \xrightarrow{s} 101$ thru $225 \xrightarrow{s} 125$	UNLIM	NO	NONE	Poisson:Mean Interarrival Times 201-210: 1.945 min 211-216: 6.060 " 217-225: 1.912 "	101-110 —> 1 111-116 —> 2 117-125 —> 3

TABLE XIX (Continued)

SOE	TRAFFIC UNIT TYPE	T/U CONV. RULE	ELEMENT CAPACITY	DELAY ACCOM	OPERATING SCHEDULE	SERVICE TIME REF.	SUCCESSOR ELEMENT
51	1-10	NONE	UNLIM	NO	Always Open	NONE	Terminal Element
52	11-16						
53	1-10						
54	11-16						
55	17-25						
56	All						
57	1-10						
58	11-16						
59	17-25						
60	All				Open 1625-1700		
61	All				Open 1600-1645		
62	1-16				Open 1200-1230	30 min.	12
63	All				Open 1200-1230	30 min.	13
64	All				Open 1200-1230	30 min.	23

TABLE XIX (Continued)

SOE	TRAFFIC UNIT TYPE	T/U CONV. RULE	ELEMENT CAPACITY	DELAY ACCOM	OPERATING SCHEDULE	SERVICE TIME REF.	SUCCESSOR ELEMENT
System II as System I except changed as follows:							
1	1-10	NONE	NA	NA	Open 0800-1130 1230-1600		5: 75% 6: 25%
2	11-16				Open 0800-1130 1230-1600		8: 75% 9: 25%
3	17-25				Open 0800-1130 1230-1600		10: 75% 11: 25%
17	All		1	NO	Open 0800-1200 1230-1630	Table XVIII	Same as 16
25	All		1	NO	Closed	Table XVIII	Same as 24
System III as System I except:							
1	1-10	NONE	NA	NA	Open 0800-1130 1230-1600		4: 75% 5: 0% 6: 25%
2	11-16				Open 0800-1130 1230-1600		7: 25% 9: 75%
15	1-16		1		Open 0800-1630	Table XVIII	All: 2% 18 8% 19 T/U 1-10 90% 26 11-16 90% 27

TABLE XX

FORM E FOR SYSTEMS II, III, IV, V, VI

SOE	TRAFFIC UNIT TYPE	T/U CONV. RULE	ELEMENT CAPACITY	DELAY ACCOM	OPERATING SCHEDULE	SERVICE TIME REF.	SUCCESSOR ELEMENT
System III (Continued)							
25	All	NONE	1	NA	Closed	Table XVIII	Same as 24
System IV as System I except:							
1	1-10	NONE	NA	NA	Open 0800-1130 1230-1600		4: 75% 6: 25%
2	11-16				Open 0800-1130 1230-1600		8: 75% 9: 25%
3	17-25				Open 0800-1130 1230-1600		10: 75% 11: 25%
15	1-10		1		Open 0800-1630	Table XVIII	All: 90% 26 2% 18 4% 19 4% 20
17	All		1		Open 0800-1630	Table XVIII	Same as 16
25	All		1		Closed	Table XVIII	Same as 24
System V as System I except:							
1	1-10	NONE	NA	NA	Open 0800-1130 1230-1600		5: 75% 6: 25%
2	11-16				Open 0800-1130 1230-1600		8: 75% 9: 25%

TABLE XX (Continued)

SOE	TRAFFIC UNIT TYPE	T/U CONV. RULE	ELEMENT CAPACITY	DELAY ACCOM	OPERATING SCHEDULE	SERVICE TIME REF.	SUCCESSOR ELEMENT
System V (Continued)							
3	17-25	NONE	NA	NA	Open 0800-1130 1230-1600		10: 75% 11: 25%
16	All		1		Open 0800-1630	Table XVIII	All: 2% 21 8% 22 T/U 1-10 90% 28 11-16 90% 29 17-25 90% 30
17	Same as 16 above						
25	All	NONE	1		Closed	Table XVIII	Same as 24
System VI as System I except:							
1	1-10	NONE	NA	NA	Open 0800-1130 1230-1600		4:75% 6: 25%
2	11-16				Open 0800-1130 1230-1600		7: 25% 9: 75%
14	1-16		1		Open 0800-1630	Table XVIII	All: 2% 18 8% 19 T/U 1-10 90% 26 11-16 90% 27

TABLE XX (Continued)

SOE	TRAFFIC UNIT TYPE	T/U CONV. RULE	ELEMENT CAPACITY	DELAY ACCOM	OPERATING SCHEDULE	SERVICE TIME REF	SUCCESSOR ELEMENT
System VI (Continued)							
15	Same as 14 above						
25	All	NONE	1	NO	Closed	Table XVIII	Same as 24
System IIA as System I except:							
1	1-10	NONE	NA	NA	Open 0800-1130 1230-1600		5: 90% 6: 10%
2	11-16				Open 0800-1130 1230-1600		8: 90% 9: 10%
3	17-25				Open 0800-1130 1230-1600		10: 90% 11: 10%
17	Same except						21: 2% 22: 3% 28,29,30: 95%
25	Closed						

TABLE XX (Continued)

SOE	TRAFFIC UNIT TYPE	T/U CONV. RULE	ELEMENT CAPACITY	DELAY ACCOM	OPERATING SCHEDULE	SERVICE TIME REF	SUCCESSOR ELEMENT
System IIB as System I except:							
1	1-10	NONE	NA	NA	Open 0800-1130 1230-1600		5: 65% 6: 35%
2	11-16				Open 0800-1130 1230-1600		8: 65% 9: 35%
3	17-25				Open 0800-1130 1230-1600		10: 65% 11: 35%
17	Same as IIA						
25	Same as IIA						
System VA as System IIA except:							
16	Same as 17						
System VB as System IIB except:							
16	Same as 17						

TABLE XX (Continued)

APPENDIX C

TOTAL WALKING TIME

POPULATION	Operating Elements														
	Sys	4	5	6	8	9	10	11	18	19	20	21	22	26	28
HIGH	I			25.28		3.91		24.02							
	II*														
	III*														
	IV	6.41		4.89	1.73	1.06	9.48	5.15	0.23	0.38	0.15	0.19	0.60	5.73	0.19
	V		8.94	5.88	2.15	1.29	10.94	5.82				0.41	0.96		8.41
	VI*														
	IIA*														
	IIB*														
	VA		9.89	1.71	2.27	0.67	9.23	1.36				0.18	0.33		9.40
	VB		9.21	9.10	2.09	1.75	8.30	6.56				0.27	1.05		8.52
AVG	I			20.44		3.36		17.25							
	II*														
	IV	4.92		4.49	1.31	0.82	9.14	4.89	0.0	0.44	0.32	0.23	0.60	4.41	0.38
	V		6.51	2.72	2.18	0.90	7.98	4.57				0.19	1.05		5.97

*System is not in balance

TABLE XXI

OUTPUT DATA SUMMARY, TOOL ROOM LOCATION STUDY

TOTAL WALKING TIME

POPULATION	Operating Elements 29	30	31 #	32	33	34	35	Total (Hrs)	(assumes 8 hrs/man) Walking % of total man-hrs	Waiting % of total man-hrs	Sys
HIGH			3	23.08	3.80	22.35	5.57	108.01	2.55	4.74	I
											II
											III
	1.65	8.55	0	5.36	1.19	6.31	3.27	62.52	1.69	0.546	IV
	1.85	9.83	0	6.56	1.30	6.78	5.74	76.86	1.836	0.508	V
											VI
											IIA
											IIB
	2.08	9.24	0	2.44	0.85	1.42	1.59	52.66	1.57	0.446	VA
	2.04	6.83	0	9.40	2.09	8.35	3.59	79.15	1.906	0.908	VB
AVG			0	19.09	2.99	16.98	6.15	86.26	2.662	0.558	I
											II
	1.35	8.25	0	5.03	0.75	5.58	6.05	50.96	1.568	0.449	IV
	1.83	7.08	0	3.02	1.13	6.02	2.79	48.50	1.595	0.178	V

TABLE XXI (Continued)

WAITING FOR SERVICE

POPULATION *		AVERAGE + MAXIMUM						CUMULATIVE HRS.			
								12	13	23	TOTAL
		Av	Max	Av	Max	Av	Max				
	N					4.19	54				
	T					0.368	0.770			201.14	201.14
	N										
	T										
	N										
	T										
H	N	0.07	4	0.30	9	0.05	3				
	T	0.022	0.117	0.069	0.258	0.018	0.099	3.20	14.61	2.38	20.19
I	N			0.32	11	0.13	6				
	T			0.039	0.150	0.039	0.178		15.17	6.12	21.29
G	N										
	T										
H	N										
	T										
	N										
	T										
	N			0.31	11	0.000	2				
	T			0.039	0.176	0.005	0.067		14.72	0.23	14.95
	N			0.20	9	0.58	14				
	T			0.028	0.133	0.141	0.400		9.67	28.04	37.71
	N					0.38	11				
A	T					0.045	0.169			18.11	18.11
	N										
V	T										
	N	0.05	4	0.18	7	0.08	5				
G	T	0.021	0.135	0.043	0.196	0.030	0.199	2.38	8.55	3.68	14.61
	N			0.08	6	0.03	3				
	T			0.013	0.091	0.015	0.081		3.75	1.66	5.41

*N = number
T = time

TABLE XXI (Continued)

NON-PRODUCTIVE

POPULATION	Total N.P. Time (hrs)	Number of Men	Total Man Hrs (8 h. ea)	TOTAL N.P. as % of Man Hrs	Sys
	309.15	530	4240	7.291	I
					II*
H					III*
	82.71	462	3696	2.237	IV
I	98.15	523	4184	2.345	V
G					VI*
					II*
H					IIB*
	67.61	419	3352	2.017	VA
	116.86	519	4152	2.814	VB
A	104.37	405	3240	3.221	I
V					II*
	65.57	406	3248	2.018	IV
G	53.91	380	3040	1.773	V

*System is not in balance

TABLE XXI (Continued)

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	20
2.	Library Naval Postgraduate School Monterey, California 93940	2
3.	Chief of Naval Operations (OP 96) Department of the Navy Washington, D. C. 20350	1
4.	Professor S. H. Parry Industrial Engineering Department The Ohio State University Columbus, Ohio 43210	1
5.	LCDR G. L. Phillips, Jr. % NROTC Unit The Ohio State University Columbus, Ohio 43210	1
6.	Project TRANSIM Department of Engineering University of California at Los Angeles Los Angeles, California	1

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) Naval Postgraduate School Monterey, California 93940	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE
Application of the General Purpose Simulator "TRANSIM" to Shipyard Tool Issue Problems

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Thesis

5. AUTHOR(S) (Last name, first name, initial)
George Lincoln Phillips, Jr., LCDR, U. S. Navy

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1967	73	3

8a. CONTRACT OR GRANT NO. b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. AVAILABILITY/LIMITATION NOTICES
[redacted]

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Naval Postgraduate School Monterey, California

13. ABSTRACT

The general-purpose simulator TRANSIM, developed by the University of California at Los Angeles, Department of Engineering, is used to study shipyard problems in the issue of tools to workers engaged in overhaul of a carrier at a Naval Shipyard. The present system, tool issue from off-ship toolrooms, is compared with proposed systems using portable auxiliary toolrooms installed aboard the ship. Two alternate locations for auxiliary toolrooms are tested in various combinations with the presently installed pierside toolrooms. A model of the present system is constructed, and extended to include the proposed alternate systems. The systems are compared using Monte Carlo techniques, at two levels of population and at three levels of auxiliary toolroom capacity. Additional refinements are recommended, and uses of the TRANSIM method in extensions of the problem are indicated.

DD FORM 1 JAN 64 1473

UNCLASSIFIED
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
TRANSIM						
SIMULATION						
SHIPYARD TOOL ISSUE						